10/532375
JC12 Rec'd PCT/PTC 21 APR 2005

[10191/3674]

IMAGING SENSOR

Background of the Invention

The present invention proceeds from an imaging sensor of the species defined in the independent claim.

WO 01/60662 A1 has already disclosed an imaging sensor that is disposed in a vehicle. It is used therein for seat occupancy detection.

Advantages of the Invention

The imaging sensor according to the present invention having the features of the independent claim has, in contrast, the advantage that the imaging sensor monitors its functionality on the basis of its image signal. A safety requirement for an image recognition system of this kind is thereby met. The imaging sensor can be used for occupant detection, for determination of the occupant's posture, or for classification of the occupancy situation, but also for surroundings monitoring and also, for example, for rollover detection. In particular, an additional sensor suite for monitoring functionality is thus no longer necessary, or the demands on additional monitoring apparatuses can be reduced. Imaging sensors are applicable here, in particular, in safety-relevant applications such as occupant protection systems. It is specifically here that functionality of the imaging sensor is essential for functionality.

The features and refinements set forth in the dependent claims make possible advantageous improvements to the imaging sensor described in the independent claim.

It is particularly advantageous that the imaging sensor has an evaluation unit that derives from the image signal at least one value that the evaluation unit compares with at least one limit value in order to monitor functionality. Empirical knowledge about measurement signal profiles can then be incorporated. It is possible in this context, in particular, to compare a limit value set that is stored in a memory associated with the imaging sensor. A system state, in particular, can be determined by the comparison with several limit values. Advantageously, that system state is then transmitted via an interface to further systems. That interface can be embodied as a two-wire interface, for example to a control unit, but it can also be embodied as a bus interface. Optical, electrical, or radio bus configurations, for example, can then be used therefor.

It is further advantageous that the imaging sensor generates the image signal on the basis of at least one invariant pattern. That invariant image signal is then used for self-monitoring by being compared with an internal reference pattern. Naturally occurring invariant features of the surroundings; or invariant features automatically induced by a system, for example using an illumination module; or artificially induced invariant features of the surroundings, for example targets that are provided or generated by a test image process, can be used for this purpose. In the test image process, a simulated sensor signal is conveyed to the evaluation unit. The associated measurement signal is predefined. Discrepancies then result in an error message.

It is further advantageous that the imaging sensor monitors its functionality on the basis of a profile of the image signal. This can be accomplished, for example, by way of a simple comparison of adjacent regions of the imaging sensor. A pattern comparison, i.e. a comparison with qualitative signal profiles, is also possible here. Trends or statistical parameters can be analyzed, or correlation methods can be applied to the image signal profile. Spectral

methods such as analysis of the Fourier spectrum, the wavelet spectrum, or the contrast spectrum can also, however, be applied here.

It is additionally advantageous that if the imaging sensor has at least two image-producing sensors, it checks its functionality by comparing the output signals of those two image-producing sensors. The redundancy of a network of high-resolution sensors, for example an array or also a stereocamera, can thereby be utilized. Methods for analysis of the image signal profile are then applicable here as well. Utilization of a time-related redundancy is also possible here, by way of a time-related analysis of the sensor signal or analysis of recorded dynamic processes.

The self-monitoring of the imaging sensor can be performed in an initialization phase or also continuously or intermittently during operation.

It is additionally advantageous that the imaging sensor is connectable to a diagnostic unit that activates the self-monitoring of the imaging sensor. That diagnostic unit can be disposed in the vehicle or also outside the vehicle, in order then to perform the self-monitoring via a radio connection. It is conceivable for an expanded test program also to be performed in the event of an activation by the diagnostic unit, since it is possible, for example, to transfer pattern files or also to perform long-term tests. It may furthermore be advantageous for the imaging sensor to be manually activatable for self-monitoring. The imaging sensor then has corresponding operating elements or interfaces for that purpose, which initiate the self-monitoring by way of an actuation of a device.

The imaging sensor can be configured, in particular, in depth-imaging fashion, i.e. two image sensors, for example, are used in order to obtain depth resolution of an object. A matrix or an array of image sensors can also be used for

this. Also conceivable is a depth-imaging sensor that operates according to different physical principles, for example the time-of-flight principle or the principle of structured illumination.

For self-monitoring but also for other purposes, it may be advantageous to have an illumination apparatus that is associated with the imaging sensor.

Drawing

Exemplified embodiments of the invention are depicted in the drawings and are explained in more detail in the description below.

In the drawings:

Figure 1 is a first block diagram of the imaging sensor according to the present invention;

Figure 2 is a second block diagram of the imaging sensor according to the present invention;

Figure 3 is a third block diagram of the imaging sensor according to the present invention;

Figure 4 is a fourth block diagram; and

Figure 5 is a fifth block diagram.

Description

Highly developed high-resolution image-producing or depth-image-producing measurement systems are of increasing interest for applications in automotive engineering. Video-based assistance systems and safety systems are envisioned here as particular applications. The more responsibility that is to be transferred from human beings, the more

reliable such a measurement system must be. In that context, the ability of the system to detect a failure and initiate suitable actions is also very important. The present invention proposes an imaging sensor of this kind that has this capability for self-monitoring, that imaging sensor being built into a motor vehicle. The essence of the invention is the integration of this self-monitoring functionality into a high-resolution image-producing or depth-image-producing measurement system.

Since such measurement systems for measured value generation have at least one high-performance evaluation unit, a self-monitoring functionality is implemented by the fact that signal processing methods are used, by way of the evaluation unit, to ascertain, from the sensor signals themselves, variables that allow conclusions as to the functional capability of the sensor and the measurement system. Previous knowledge and empirical knowledge about signal profiles is evaluated in suitable fashion. In the simplest case, a parameter that has been derived from the image signal is compared with a limit value or a limit value set that is stored in a memory associated with the imaging sensor.

Another possibility is to perform an evaluation of the system status on the basis of several different variables. If limit values are exceeded or if a limited functionality (up to and including sensor failure) is identified in another fashion, a corresponding status report is then transmitted via a suitable interface, but at least the failure of the imaging sensor is reported. Otherwise the functional capability of the imaging sensor is transmitted via that interface. The self-monitoring can be performed during the initialization phase of the imaging sensor, at certain points in time or continuously. The self-monitoring can also be activated externally, i.e. by way of a higher-order system such as a diagnostic unit, or manually. It is conceivable, in the case of activation by way of a

diagnostic system, also to perform an expanded test program, since it is possible, for example, to transfer pattern files or also to perform long-term tests.

Figure 1 shows the imaging sensor according to the present invention in a first block diagram. Physical process 10 (the scene) is imaged by sensor 12 as an image signal. Sensor 12, together with a processing unit 13, constitutes a measurement system. The image signal generated by sensor 12 is prepared and processed by processing unit 13. The measurement signal, i.e. the image signal, is transferred via a first interface 14 to further systems, for example to a control unit for occupant detection.

The status of the imaging sensor which is presented here, and which was also determined on the basis of the image signal, is transferred via a further interface 15. As stated above, the status of the imaging sensor, i.e. its self-monitoring, is performed either by utilizing previous knowledge about its invariant patterns, or empirical knowledge about measurement signal profiles or the redundancy of a network of sensors, or by utilizing time-related redundancy. Interfaces 14 and 15 can also be combined into one interface and are then separated only logically. The interfaces here can be two-wire interfaces or also interfaces to a bus system.

Figure 2 shows an imaging sensor that has more than one sensor for image acquisition and is thus also configured for depth-image production. Three sensors 22 through 24 are depicted here by way of example, although it is possible to use only two sensors or also more sensors. Measurement system 21 is therefore constituted by sensors 22 through 24 and processing unit 25. Physical process 20 (the scene) is imaged by sensors 22-24. Processing unit 25 receives the image signals of image sensors 22 through 24, processes them, and then, as a function of the evaluation of those image signals, conveys signals to interfaces 26 and 27 in

order to transfer on the one hand the status of the imaging sensor and on the other hand the measurement signal itself. Sensors 22 through 24 can be connected to individual interface modules of processing unit 25, but they can also be connected to processing unit 25 via a multiplexer or an internal bus. The imaging sensor can be embodied in one physical unit in which interfaces 26 and 27 are also integrated. Another possibility, however, is that no housing exists for the entirety of these components, and instead they are disposed in distributed fashion. Processing unit 25 then, as described above, performs the analysis of the image signal in order to perform the self-monitoring of the imaging sensor.

Figure 3 shows the imaging sensor according to the present invention in a third block diagram. Two sensors are present here, as video cameras 31 and 32 that are connected to a processing unit 33. The latter has a program 34 for sensor data processing and a program 35 for self-monitoring. Self-monitoring 35 is also performed on the image signals of video cameras 31 and 32. In addition, processing unit 33 controls an illumination unit or a signal generator 36, for example in order to perform the self-monitoring by comparing self-induced patterns with their internal representation. Processing unit 33 is furthermore connected to interfaces 37 and 38 that serve to transfer respectively the measurement signal, i.e. the image or depth image, and the status or the result of the self-monitoring. Measurement system 30 thus comprises video cameras 31 and 32, processing unit 33, and illumination unit 36. The overall imaging sensor is supplemented with interfaces 37 and 38. Sensors 31 and 32 are embodied here as video cameras. The output signals are conveyed to evaluation unit 33, which performs suitable processing steps such as image processing, correlation methods, or triangulation in order to generate the spatial data. This processing unit 33 also, however, performs suitable processes for self-monitoring of the measurement system. In this exemplified embodiment, the output signals

of the stereoscopic video measurement system are the image, the depth image, and the status signal of measurement system 30.

The table below lists potential problems that can result in limited functionality of the embodied measurement system. Columns 2 and 3 contain the appropriate data and signal processing methods for identifying the limited functionality.

Problem	Data analyzed	Selection of self-monitoring methods
Sensor is (partly) obstructed	Grayscale image of sensor 1	Utilize previous knowledge about invariant patterns: ● Naturally occurring invariant features of the surroundings. ● Invariant features induced automatically (e.g. using an illumination module) by the system. Utilize time-related redundancy: ● Time-related analysis of sensor signal. ● Analysis of recorded dynamic processes.
	Grayscale image of sensor 2	see Grayscale image of sensor 1
	Grayscale images of sensors 1 and 2	Utilize empirical knowledge about measurement signal profiles: ● Analysis of statistical parameters Utilize redundancy of a network of high-resolution sensors: compare various individual sensor signals of the sensor network
	Depth image	see Grayscale image of sensor 1
Decalibration detection	Grayscale image of sensor 1	Utilize previous knowledge about invariant patterns: ● Naturally occurring invariant features of the surroundings. ● Invariant features induced automatically (e.g. using an illumination module) by the system.
	Grayscale image of	see Grayscale image of sensor 1

	sensor 2	
	Grayscale images of sensors 1 and 2	Utilize redundancy of a network of high-resolution sensors: compare various individual sensor signals of the sensor network
Errors in brightness setting	Grayscale image of sensor 1	Utilize empirical knowledge about measurement signal profiles: • Simple comparison of adjacent regions of sensor • Comparison with limit values • Comparison with qualitative signal profiles • Analysis of trends • Analysis of statistical parameters • Analysis of further spectral properties Utilize time-related redundancy: • Time-related analysis of sensor signal. • Analysis of recorded dynamic processes.
	Grayscale image of sensor 2	see Grayscale image of sensor 1
	Grayscale images of sensors 1 and 2	Utilize redundancy of a network of high-resolution sensors: compare various individual sensor signals of the sensor network
Errors in image sharpness (defocusing)	Grayscale image of sensor 1	Utilize empirical knowledge about measurement signal profiles: • Analysis of statistical parameters • Analysis of contrast spectrum • Analysis of further spectral properties Utilize time-related redundancy:

		• Time-related analysis of sensor signal. • Analysis of recorded dynamic processes.
	Grayscale image of sensor 2	see Grayscale image of sensor 1
	Grayscale images of sensors 1 and 2	Utilize redundancy of a network of high-resolution sensors: compare various individual sensor signals of the sensor network

A stereoscopic video-based measurement system may be regarded as a typical example of a high-resolution image-producing or depth-image-producing measurement system to which many of the aforementioned signal-processing or pattern-recognition methods can be applied for self-monitoring. A largely independent generation of the individual sensor signals, in particular, should make possible a powerful self-monitoring functionality.

Figure 4 is a fourth block diagram of the imaging sensor according to the present invention. A video sensor system 40 has a camera system 42 that is connected on the one hand to an image preprocessor 43 and on the other hand to an output of the video sensor system. Image preprocessor 43 is connected to a comparison unit 44 that is connected via an output to an evaluation unit 45 and via an input to a device for structured illumination. Evaluation unit 45 supplies the sensor status via an output of video sensor system 40.

Device 41 for structured illumination radiates structured light, constituting a reference pattern, into the surroundings of video sensor system 40, in particular onto a surface 47 on which the reference pattern is imaged. That surface is then referred to as reference surface 47. Reference surface 47 is rigid and stationary. Conceivable reference surfaces are object surfaces present in the sensing region of video sensor system 40, for example a roof

liner when the sensor is used to monitor a motor vehicle interior. Also possible, however, are special calibration elements that, for example, are mounted in a defined location and orientation during the manufacturing process.

Camera system 42, which can comprise one or more cameras, senses the reference pattern on reference surface 47. The two-dimensional camera images are compared in comparison unit 44 to the reference pattern; the two-dimensional camera images can also be ones that were prepared in the optional image preprocessor 43. That preparation can be a filtration. Comparison unit 44 can have a memory unit in which, for example, the reference patterns are stored, if they are not conveyed from the unit for structured illumination in the form of a signal. The sensor status is then ascertained in evaluation unit 45 on the basis of the results of comparison unit 44. The fact that the sensor is obstructed or unobstructed and/or the sensor optics are focused or unfocused and/or the optical image is distorted or undistorted can be regarded, for example, as the sensor status. Evaluation unit 45 can also contain a memory in which, for example, specific patterns can be stored that are created upon comparison of the reference pattern with the camera images of a faulty video sensor system.

With the device described above it is possible, for example, to identify a defocusing of the sensor by analyzing whether a sharp image of the reference pattern is present in the camera image. Complete or partial obstruction of the sensor can furthermore be detected by checking whether the reference pattern is imaged in complete and undistorted fashion in the camera image. Distortions of the optical image result in distorted imaging of the reference pattern in the camera image, and can thus be identified using comparison unit 44 and evaluation unit 45. Further errors that can detected with this system are soiling of the optics, and misalignment of the absolute calibration. Here the resulting shift and distortion of the reference pattern

is detected. An initial calibration or post-calibration can in fact be performed on these data.

Device 41 for structured illumination can be integrated into the video sensor. A device for structured illumination separate from the video sensor is also possible, however, especially in the manufacturing process and for checking the video sensor at a repair shop. In this case a defined orientation of the device for structured illumination with respect to the video sensor is necessary. With this procedure, therefore, in the simplest case the video image of the structured illumination is interpreted directly. An evaluation of a three-dimensional image is also possible.

Figure 5 is a further block diagram. A video sensor system 50 has two cameras 52 and 53 that supply their respective camera images to a unit 54 for determining three-dimensional measured values. A three-dimensional point cloud then results therefrom and is conveyed on the one hand to a signal preprocessor 55 and on the other hand to an output of video sensor system 50. Signal preprocessor 55 is connected to a comparison unit 56 to which a device 51 for structured illumination is also connected. Comparison unit 56 is connected via a data output to an evaluation unit 57 that in turn outputs the sensor status.

Device 51 for structured illumination illuminates a reference surface in surroundings 58 of the video sensor. The reflected pattern is acquired by cameras 52 and 53. Unit 54 determines the three-dimensional point cloud from the camera images based on the stereo measurement principle. In addition to determination of the three-dimensional point cloud, the two-dimensional camera images can also be evaluated directly. A further possibility lies in evaluating the three-dimensional measured values using a range sensor that operates on the time-of-flight principle.